



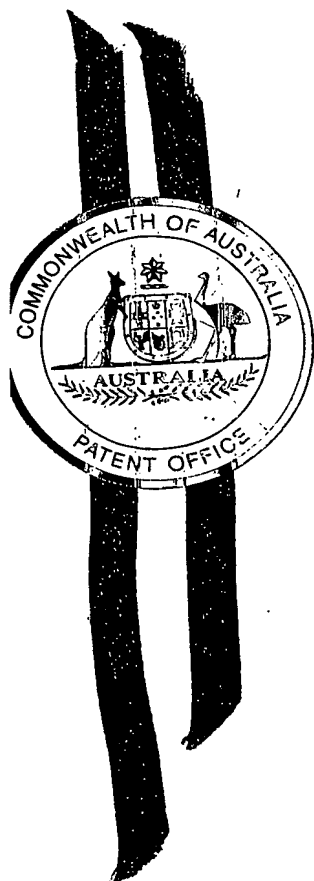
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JULIE BILLINGSLEY  
TEAM LEADER EXAMINATION  
SUPPORT AND SALES

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**APPLICANT: HEYRING TECHNOLOGIES PTY LTD**

**AUSTRALIA**  
**PATENTS ACT 1990**  
**PROVISIONAL SPECIFICATION**

**FOR THE INVENTION ENTITLED:**

**"A WATER CRAFT"**

**The invention is described in the following statement:-**

## A WATER CRAFT

### Field of the Invention

- 5 The present invention relates to a water craft and, in particular, to displacement-type water craft and planing-type water craft.

### Background of the Invention

- 10 It is known to provide a displacement-type water craft which operates such that as the water craft moves through the water a mass of water is displaced from a front portion to a rear portion of the water craft.

- At relatively low speed, the water craft is capable of moving relatively efficiently  
15 through a body of water. However, when the water craft moves relatively quickly through a body of water, a much larger volume of water is required to be displaced which causes significant turbulence and a consequent need for a significant amount of power from the engine of the water craft. This effect is increased when waves are encountered by the water craft since the water craft will cut relatively deep into the body  
20 of water when the water craft passes through a wave crest.

- Furthermore, displacement-type water craft also tend to provide a passenger with an uncomfortable ride and an increased risk of sea sickness since the body of the water craft generally follows the surface of the water.

- 25 In order to overcome some of the disadvantages of displacement-type water craft, it is known to provide planing-type water craft which rise up relative to a body of water and plane across the surface of the body of water when the water craft attains sufficient speed. This allows the water craft to move much faster across the body of water using  
30 less energy than displacement-type water craft.

However, if the surface of the body of water is not relatively flat, an uncomfortable

jarring motion occurs as a result of heavy impact between the water craft and each successive wave front. In relatively rough water, such planing-type water craft are unable to achieve planing speed and are compelled to move relatively slowly and inefficiently as displacement-type water craft.

5

A further alternative is to provide a water craft with two or more elongate narrow hulls which slice through the water more economically and more comfortably than relatively wide single hull water craft.

- 10 However, such multi hull-type water craft are prone to accident because they are of rigid construction; in some circumstances, for example in relatively rough conditions, at least one hull lifts from the water surface while the other hull(s) become submerged. As a consequence, extreme forces are localised within parts of the structure which can cause the craft to break or capsize.

15

- In order to increase speed and comfort by reducing the contact surface area between the or each hull of the water craft and a body of water, hydrofoil-type water craft have been produced. With such hydrofoil-type water craft, submerged wings are provided such that when the water craft reaches a particular speed, the wings produce sufficient lift to  
20 raise the craft out of the water. Since the wings are completely submerged and cut through the water rather than travelling on the surface of the water, hydrofoil-type water craft require considerable engine power to raise the or each hull out of the body of water during use. In addition, the drag caused by the submerged wings causes the water craft to be very inefficient when moving slowly. Hydrofoil-type water craft are also unable to  
25 operate in relatively shallow waters as the wings and engine propellers tend to extend a few metres below the water surface when the water craft is moving slowly or is at rest.

#### Summary of the Invention

- 30 In accordance with an aspect of the present invention, there is provided a water craft including:  
a chassis portion;

at least two side water engaging means;

at least one front water engaging means disposed forwardly of said side water engaging means;

5 at least one rear water engaging means disposed rearwardly of said side water engaging means;

each side, front and rear water engaging means being connected to the chassis portion and being moveable in a substantially vertical direction relative to the chassis portion; and

10 interconnection means arranged to functionally link said side, front and rear water engaging means such that, in use, movement of at least one of said water engaging means effects movement of at least one of said other water engaging means so that the chassis portion is encouraged to maintain a substantially stable inclination.

15 In one arrangement, the interconnection means is arranged to functionally link the water engaging means such that when one of the water engaging means is urged during use to move in a generally vertical direction relative to the chassis portion, an adjacent two water engaging means are urged to move in a generally opposite vertical direction.

20 Preferably, each water engaging means is interconnected to an adjacent two water engaging means such that when one of the water engaging means is urged during use to move in a generally vertical direction relative to the chassis portion, the adjacent two water engaging means are urged to move in a generally opposite vertical direction.

25 In one arrangement, the interconnection means is arranged to functionally link the water engaging means such that when two adjacent water engaging means are urged during use to move in the same generally vertical direction relative to the chassis portion, an opposite two adjacent water engaging means are restricted from moving in a generally opposite vertical direction relative to the chassis portion.

30 In one embodiment, at least one pair of adjacent water engaging means is functionally linked to a diagonally oppositely located pair of adjacent water engaging means such that when the pair of water engaging means are urged to move in the same generally

vertical direction relative to the chassis portion, the diagonally oppositely located pair of water engaging means are restricted from moving in a generally opposite vertical direction relative to the chassis portion.

- 5 In an alternative embodiment, at least one pair of adjacent water engaging means is functionally linked to a transversally oppositely located pair of adjacent water engaging means such that when the pair of water engaging means are urged to move in the same generally vertical direction relative to the chassis portion, the transversely oppositely located pair of water engaging means are restricted from moving in a generally opposite
- 10 vertical direction relative to the chassis portion.

In one arrangement, the water engaging means are arranged in a generally diamond shaped configuration. Any number of water engaging means may be provided, preferably four.

15

In an alternative arrangement, the water engaging means are arranged in a generally square or rectangular shaped configuration. Any number of water engaging means may be provided, preferably four or six.

- 20 In one embodiment, the interconnection means includes mechanical connections to functionally link the water engaging means. In addition, or alternatively, the interconnection means includes fluid connections to functionally link the water engaging means. The fluid connections may be hydraulic and/or pneumatic connections.

25

In embodiments wherein the interconnection means includes mechanical connections, each water engaging means may be mounted on a leg and the water craft may include drop links or gears to interconnect adjacent legs of the water craft.

- 30 In one embodiment, the mechanical connections are arranged such that the amount of weight borne by the water engaging means is equal.

In embodiments wherein the interconnection means includes fluid connections, each water engaging means may be mounted on a leg and the fluid connections may include rams and interconnecting fluid conduits to interconnect legs of the water craft.

5 Preferably, the rams and fluid conduits define a plurality of discrete fluid circuits, at least some of the fluid circuits including a first fluid circuit portion extending between upper chambers of two adjacent rams, a second fluid circuit portion extending between lower chambers of an oppositely located two adjacent rams, and a third fluid circuit portion extending between the first fluid circuit portion and the second fluid circuit  
10 portion.

In one embodiment, at least one of the fluid circuits is provided with at least one accumulator and/or at least one damping device. The damping device may be a regenerative damping device arranged to provide variable damping.  
15

In one arrangement, the water craft includes control means arranged to control and facilitate adjustment of the height and orientation of the chassis portion relative to the water engaging means. The control means may include a plurality of sensors for sensing characteristics of the water craft and a control unit for adjusting the amount of fluid in  
20 the fluid circuits in response to signals generated by the sensors.

#### Brief Description of the Drawings

The present invention will now be described, by way of example only, with reference to  
25 the accompanying drawings, in which:

Figure 1 is a diagrammatic perspective view of a water craft in accordance with an embodiment of the present invention;

Figure 2 is a diagrammatic plan view of the water craft shown in Figure 1;

Figure 3 is a diagrammatic side view of the water craft shown in Figures 1 and 2;

30 Figure 4 is a diagrammatic front view of the water craft shown in Figures 1 to 3;

Figure 5 is a diagrammatic side view of the water craft shown in Figures 1 to 4 with the water craft shown during use travelling across a wave peak;

Figure 6 is a diagrammatic side view of the water craft shown in Figures 1 to 4 with the water craft shown during use travelling across a wave trough;

Figure 7 is a diagrammatic perspective view of a water craft in accordance with a further alternative embodiment of the present invention;

5 Figure 8 is a diagrammatic plan view of the water craft shown in Figure 7;

Figure 9 is a diagrammatic side view of the water craft shown in Figures 7 and 8;

Figure 10 is a schematic diagram illustrating operation of hydraulic circuits of the water craft shown in Figures 7 to 9;

10 Figure 11 is a schematic diagram illustrating a control circuit for the water craft shown in Figures 7 to 9;

Figure 12 is a diagrammatic plan view of a water craft in accordance with a further alternative embodiment of the present invention;

Figure 13 is a schematic diagram illustrating a regenerative damper system for a water craft in accordance with the present invention; and

15 Figure 14 is a schematic diagram illustrating an alternative regenerative damper system for a water craft in accordance with the present invention.

#### Description of a Preferred Embodiment of the Present Invention

20 Referring to Figures 1 to 4 of the drawings, there is shown a water craft 10 in accordance with an embodiment of the present invention.

The water craft 10 includes a chassis 12, in this example of I-shaped configuration, a front leg 14 pivotably connected to the chassis 12 at first leg hinge connections 16, a  
25 right side leg 18 pivotably connected to the chassis 12 at right leg hinge connections 20, a rear leg 22 pivotably connected to the chassis 12 at rear leg hinge connections 24, and a left side leg 26 pivotably connected to the chassis 12 at left leg hinge connections 28.

30 Ends of the front, rear and side legs 14, 18, 22, 26 are provided with respective water engaging means which may be a ski, float or any other suitable water engaging device. In this specification, the water engaging means will be referred to as "pods" for ease of reference.



An end of the front leg 14 remote from the chassis 12 is provided with a front pod 30 pivotably connected to the front leg at a front pod hinge connection 32. An end of the right side leg 18 remote from the chassis 12 is provided with a right pod 34 pivotably  
5 connected to the right side leg 18 at a right pod hinge connection 36. An end of the rear leg 22 remote from the chassis 12 is pivotably connected to a rear pod 38 at a rear pod hinge connection 40. An end of the left side leg 26 remote from the chassis 12 is pivotably connected to a left pod at a left pod hinge connection 44.

10 It will be understood that the front, right, rear and left leg hinge connections 16, 20, 24, 28 facilitate movement of the pods in a generally vertical direction during use. Similarly, it will be understood that the front, right, rear and left pod hinge connections 32, 36, 40, 44 facilitate pitch-type movement of the front and rear pods 30, 38 and roll-type movement of the side pods 34, 42.

15 The front leg 14 includes two first front members 46 and two second front members 48, the first and second front members 46, 48 being connected together at the front leg hinge connections 16. The length of the second front members 48 is approximately one third the length of the first front members 46 such that movement of the front pod 30 in  
20 a generally vertical direction over a first distance causes movement of free ends of the second front members 48 in a generally opposite vertical direction over a second distance approximately one third of the first distance.

Each of the side legs 18, 26 includes two side members 52 extending between respective  
25 side leg hinge connections 20, 28 and a respective right or left pod 34, 42.

Similarly with the front leg 14, the rear leg 22 includes first rear members 54 and second rear members 56 which meet at the rear hinge connections 24. As with the front leg 14, the length of the second rear members 56 is approximately one third the length of the  
30 first rear members 54 such that movement of the first rear members 54 in a generally vertical direction over a first distance causes the second rear members 56 move in a generally opposite vertical direction over a second distance approximately one third of

the first distance.

Free ends of the second front members 48 and the second rear members 56 are provided with drop links 57, each of which extends between a respective second front or second rear member 48, 56 and a side member 52 of a side leg 18, 26. The front and side legs 14, 18, 22, 26 are interconnected so that movement of one of the front and rear legs 14, 22 in a generally vertical direction causes movement of the other of the front and rear legs 14, 22 in the same vertical direction and movement of the side legs 18, 26 in a generally opposite vertical direction. Similarly, movement of one of the side legs 18, 26 in a generally vertical direction causes movement of the other of the side legs 18, 26 in the same generally vertical direction, and movement of the front and rear legs 14, 22 in a generally opposite vertical direction. The position of the drop links 57 relative to the legs affects the degree of arcuate movement of the legs during use and the amount of weight borne by each pod.

It will be understood that while the drop links 57 are connected at ends of the front and rear legs 14, 22 and each of the front and rear hinge connections 16, 24 is disposed between ends of a respective front or rear leg 14, 22, the side legs 18, 26 have an opposite arrangement in that each of the drop links is connected at a location between ends of a respective side leg 18, 26 and each of the side hinge connections 20, 28 is disposed at an end of a respective side leg 18, 26. This arrangement facilitates opposite movement of adjacent legs during use.

It will be understood that by facilitating movement of the legs in this way, substantially equal loading on the front, rear and side pods during use is encouraged and the chassis 12 is encouraged to maintain a substantially stable inclination as the water craft progresses through an uneven water surface.

It will also be understood that similar operation can be achieved by disposing free ends of the front and rear legs 14, 22 above the side legs 18, 26 instead of below the side legs. However, with this arrangement, the drop links 57 would ordinarily be in compression instead of tension.

As shown in Figure 4, underside surfaces 58 of the pods may be contoured depending on the required application, for example so that side slippage of the side pods of the water craft during use is restricted, and so that the front and rear pods may move  
5      sideways to facilitate turning of the craft.

The present embodiment is illustrated in use in Figures 5 and 6 which show the water craft 10 travelling across a crest and a trough of a wave.

10      As shown in Figure 5, as the water craft 10 passes over a crest 60 of a wave, the front, rear and side legs 14, 18, 22, 26 are urged to move downwardly relative to the chassis 12 and the side legs 18, 26 are urged to move upwardly relative to the chassis so that the pods 30, 36, 40, 44 all contact the water surface 62 and substantially equal loading is encouraged on the pods. Similarly, as shown in Figure 6, when the water craft 10 passes  
15      over a trough 63, the front and rear legs 14, 22 are urged to move upwardly relative to the chassis 12 and the side legs 18, 26 are urged to move downwardly relative to the chassis 12 so that substantially equal loading is maintained on the pods and so that an average level inclination of the chassis between the pods is encouraged.

20      The water craft 10 of the above described embodiment includes legs 14, 18, 22, 26 of approximately equal length with the distance from the leg hinge connections 16, 20, 24, 28 to respective drop links 57 being approximately equal. As a consequence, any weight applied to the chassis 12 will be substantially equally shared by all four pods.

25      However, it will be understood that since the lengths of the legs and the positions of the drop links determines the degree of arcuate movement of the legs during use and the amount of weight borne by each pod, the lengths of the legs and positions of the drop links may be modified depending on the desired weight bearing characteristics of the water craft.

30

It will also be understood that the drop links 57 may be resilient and/or may include damper means so as to absorb rapid pod motions and four-pod heave motions. For

example, the drop links 57 could be formed of rope material, bungy rubber, and so on. In alternative arrangements wherein the drop links are ordinarily in compression, a compression spring or a device of similar function may be used. The damper means may include a shock absorber in parallel with a drop link.

5

It will also be understood that other mechanical arrangements which operate in a similar way are possible.

10 For example, instead of providing hinge connections 16, 20, 24, 28 and drop links 57 to facilitate movement of the front and rear pods 30, 38 simultaneously with and in an opposite direction to the left and right pods 34, 42, gears may be provided, each leg having at least two associated gears and each gear meshing with a gear of an adjacent leg so as to transfer movement between the legs.

15 Referring to Figures 7 to 10 of the drawings, there is shown a further alternative water craft 77 in accordance with a further alternative embodiment of the present invention. Like features are indicated with like reference numerals.

20 The water craft 77 operates in a similar way to the water craft shown in Figures 1 to 6 except that legs of the water craft 77 are interconnected using hydraulic circuits instead of mechanical connections.

The water craft 77 includes an alternative chassis 78 having an upper chassis portion 79 and a lower chassis portion 80 connected by links 81.

25

30 A front leg 82 is pivotably connected to the lower chassis portion 80 at front leg hinge connections 83, a right side leg 84 is pivotably connected to the lower chassis portion 80 at right leg hinge connections 85, a rear leg 86 is pivotably connected to the lower chassis portion 80 at rear leg hinge connections 88, and a left side leg 90 is pivotably connected to the lower chassis portion 80 at left leg hinge connections 92.

Ends of the front, right side, rear and left side legs 82, 84, 86, 90 are provided with

respective front, right side, rear and left side pods 30, 34, 38, 42.

- Flexibly connected to and extending between the front leg 82 and the upper chassis portion 79 are a double acting front right ram 94 and a double acting front left ram 96.
- 5 Flexibly connected to and extending between the right side leg 84 and the upper chassis portion 79 are a double acting right front ram 98 and a double acting right rear ram 100. Flexibly connected to and extending between the rear leg 86 and the upper chassis portion 79 are a double acting rear right ram 102 and a double acting rear left ram 104. Flexibly connected to and extending between the left side leg 90 and the upper chassis
- 10 portion 80 are a double acting left front ram 106 and a double acting left rear ram 108.

- In this example, each ram is a hydraulic ram, a cylinder portion of each ram being connected to the upper chassis portion 79 and a piston portion of each ram being connected to a leg. In this way, the surface area of the piston in the upper chamber of
- 15 each ram is greater than the surface area of the piston in the lower chamber of each ram.

- Upper chambers of the front right ram 94 and the rear front ram 98 are connected together in fluid communication and lower chambers of the front right ram 94 and the right front ram 98 are connected together in fluid communication by an upper front right
- 20 conduit 110 and a lower front right conduit 112 respectively. Upper chambers of the right rear ram 100 and the rear right ram 102 are connected together in fluid communication and lower chambers of the right rear ram 100 and the rear right ram 102 are connected together in fluid communication by an upper rear right conduit 114 and a lower rear right conduit 116 respectively. Upper chambers of the rear left ram 104 and
- 25 the left rear ram 108 are connected together in fluid communication and lower chambers of the rear left ram 104 and the left rear ram 108 are connected together in fluid communication by an upper rear left conduit 118 and a lower rear left conduit 120 respectively. Upper chambers of the front left ram 96 and the left front ram 106 are connected together in fluid communication and lower chambers of the front left ram 96
- 30 and the left front ram 106 are connected together in fluid communication by an upper front left conduit 122 and a lower front left conduit 124 respectively.

The lower front right conduit 112 is connected in fluid communication with the upper rear left conduit 118 by a first link conduit 126. The upper front right conduit 110 is connected in fluid communication with the lower rear left conduit 120 by a second link conduit 128. The upper front left conduit 122 is connected in fluid communication with the lower rear right conduit 116 by a third link conduit 130. The lower front left conduit 124 is connected in fluid communication with the upper rear right conduit 114 by a fourth link conduit 132.

The water craft 77 also includes several accumulators 134 and damper valves 136 disposed in circuit with the conduits, the accumulators serving to absorb rapid leg movements during use, and the damper valves serving to control the rate of fluid flow so as to prevent the craft from bouncing.

For ease of reference, the rams 94, 96, 98, 100, 102, 104, 106, 108 and interconnecting conduits 110, 112, 114, 116, 118, 120, 122, 124, 126, 128, 130, 132 are shown diagrammatically in Figure 12. Although in this Figure no accumulators or damper valves are shown, it will be understood that in practice, accumulators and damper valves would be present.

Operation of the water craft 77 will now be described with reference to Figures 9 to 12. When the water craft 77 is at rest on relatively flat water, the weight of the water craft 77 is substantially equally borne by the rams which are held in compression between the upper chassis portion 79 and the legs.

Under normal conditions, piston rods of the rams would be statically adjusted such that heads of the piston rods locate generally centrally of respective ram cylinders. This ensures that an equal amount of extension and contraction of the rams is possible. The diameter and length of the piston rods as well as the amount of gas in the accumulators determines the spring rates for the craft. For example, it will be understood that an increase in spring rate may be achieved by increasing the diameter of the piston rods or by reducing the amount of gas in the accumulators.

Under normal usage, when the water craft is stationary and an additional load is applied to the water craft, the rams become additionally compressed which causes their overall length to reduce, a volume of fluid equivalent to the extra volume of piston rod introduced into the hydraulic circuits to be accommodated in the accumulators, and the  
5 volume of gas in the accumulators to reduce. In order to reset the normal optimum travelling ride height of the water craft after a load has been applied, additional fluid would be introduced into the hydraulic circuits.

If during use the front pod 30 encounters a wave crest, the front leg 82 is caused to  
10 move upwards relative to the chassis 78 thereby causing compression of the front right ram 94 and the front left ram 96. This causes an increase in fluid pressure in the upper chambers of the front right ram 94 and the front left ram 96 and a corresponding increase in fluid pressure in the upper front right conduit 110 and the upper front left conduit 122. This causes fluid to flow from the upper chambers of the front right ram  
15 94 and the front left ram 96 to the upper chambers of the right front ram 98 and the left front ram 106. This causes the right front ram 98 and the left front ram 106 to extend as the upper chambers of these rams are enlarged to accommodate the fluid volume from the increased fluid pressure in the upper front right conduit 110 and the upper front left conduit 122. As a result, the right and left side legs 84, 90 move downwards relative to  
20 the chassis 78.

Since the right rear ram 100 and the left rear ram 108 are also connected between a respective side leg 84, 90 and the chassis 78, as the side legs 84, 90 move downwardly relative to the chassis, the right rear ram 100 and the left rear ram 108 also extend. This  
25 causes the upper chambers of the right rear ram 100 and the left rear ram 108 to enlarge and the fluid pressure in the upper chambers of these rams to reduce. This causes fluid to flow from the upper chambers of the rear right ram 102 and the rear left ram 104 to the upper chambers of the right rear ram 100 and the left rear ram 108 which permits the rear right ram 102 and the rear left ram 104 to contract under the weight of the craft. As  
30 a result, the rear leg 86 moves upwardly relative to the chassis 78 in order to substantially equalise the pressure and weight borne by each ram.

It will be understood, therefore, that each leg is provided with two double acting rams which are mechanically connected to each other and which are each hydraulically connected to a ram of an adjacent leg. As a consequence, movement of one of the legs in a generally vertical direction tends to cause movement of an adjacent leg in an opposite vertical direction, and movement of an opposite leg in the same direction.

However, when the water craft 77 is moving relatively quickly across a body of water, in order to promote a more comfortable ride, accumulators and damping valves are provided which obscure the tendency of one of the legs to cause movement of the other legs.

If during use the water craft 77 experiences a pitch and roll type force which tends to submerge adjacent pods and tilt the body of the water craft, for example the front and right pods 30, 34, and which tends to raise the opposite pods, for example the rear and left pods 38, 42, the water craft will experience an apparent weight shift which causes the front right ram 94 and the right front ram 98 to contract and the rear left ram 104 and the left rear ram 108 to expand. Since the upper chambers of the front right ram 94 and the right front ram 98 will experience substantially the same increase in pressure and the lower chambers of the rear left ram 104 and the left rear ram 108 will experience substantially the same increase in pressure, a pressure differential is created across the pistons of the front right ram 94, the right front ram 98, the rear left ram 104 and the left rear ram 108. The increased pressure in the lower chambers of the rear left ram 104 and the left rear ram 108 urges the rear left ram 104 and the left rear ram 108 to contract so as to increase the volume of fluid in the lower chambers of the rear left ram 104 and the left rear ram 108. As a result, the rear leg 86 and the left leg 90 are urged to move upwardly relative to the chassis 78 so as to prevent a left rear portion of the chassis 78 from lifting relative to a front right portion of the chassis 78.

It will be understood, therefore, that when two or more adjacent legs of the water craft 77 are urged to move in the same generally vertical direction relative to the chassis 78, the other legs are also urged to move in the same direction.



It will also be understood that although the abovementioned hydraulic circuits act to restrict roll and pitch motions of the water craft, individual motions of the legs are not restricted. The water craft is consequently able to move in a cross-wind without keeling over whilst allowing each pod to move relative to its adjacent pods.

5

Although the above alternative embodiment has been described in relation to a water craft 77 which includes legs pivotably connected to a lower chassis portion 80, it will be understood that other arrangements for moveably connecting the pods to the chassis are possible. For example, the legs may be replaced by double wishbones. An advantage of this arrangement is that in addition to causing generally vertical movement of a pod, the wishbones may also be designed to cause the pod to tilt, for example so that when a pod loses contact with the water a front portion of the pod does not dig into the water on re-entry. Additionally, when the side pods move up and down through an arc relative to the chassis, the side pods may be caused to stay parallel to the craft and the average water level.

10

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As shown in Figures 7 to 9, each of the four discrete hydraulic circuits formed by upper chambers of an adjacent two rams, lower chambers of an adjacent opposite two rams and a conduit interconnecting the chambers in this example is provided with at least one accumulator, in this example hydraulic accumulators 134, and normally at least one damper. However, it will be understood that any number and type of accumulators and dampers may be provided depending on the level of resilience and damping required.

20

In one example, each accumulator 134 is provided with a damper valve adjacent a fluid entry port of the accumulator 134 to reduce the speed of fluid passing into and out of the accumulator. The damper valve also serves to facilitate control of the degree of restriction to fluid flow so as to thereby control bounce/heave.

25

In one example, each ram is provided with a damper valve, generally associated with an upper chamber of the ram, so as to facilitate control of movement of the rams. Two damper valves may also be disposed in circuit with each of the link conduits 126, 128, 130, 132, one damper valve being disposed adjacent each longitudinal end of a link

30

conduit so as to facilitate specific control of roll and pitch motions.

Each accumulator 134 may be of any suitable type, such as of bladder or piston configuration and may be provided with a variable damper valve mechanism at the fluid entry port. The characteristics of the damper valves may be varied by selecting appropriate deformable shims, or by more complex needle or spool valves, or by solenoids optionally controlled using an electronic control unit (ECU) in response to signals from a plurality of sensors disposed at various locations on the water craft 77, and so on.

10

It will be understood that the function of the accumulators and damper valves is to provide a degree of resilience to accommodate rapid pod motions and to resolve spike loads which could cause a jarring ride and traumatise components of the water craft. In particular, the accumulators and damper valves are of primary importance when the water craft 77 is travelling relatively quickly. At relatively slow speeds, when the water craft is travelling through relatively smooth waves, the front and rear pods will tend to move together in one direction while the left and right pods tend to move together in an opposite direction with fluid being transferred between chambers of adjacent rams. However, when the water craft is travelling relatively fast and the conditions experienced by the water craft are relatively rough, instead of promoting opposite movement of diagonally opposite ram pairs, a degree of resilience is required to absorb rapid pod motions.

15  
20

In the present example, the accumulators 134 and associated damper valves 136 are disposed generally centrally of the first, second, third and fourth link conduits 126, 128, 130, 132, as this location is particularly suitable for absorbing minor and rapid pod movements without undue mass effects and without excessive damping which can occur as a result of excessively long conduit paths. However, it will be understood that the accumulators may be located at other locations in the hydraulic circuits and additional accumulators and/or damping devices may be provided depending on the requirements.

25  
30

Damping may also be accomplished using point restrictors or by narrowing any of the

conduits.

- The water craft 77 may also include means for controlling the orientation of the pods relative to their respective legs. For this purpose, the front pod 30 has an associated front pod ram 138 and a front pod position sensor 140, the right pod 34 has an associated right pod ram 142 and a right pod position sensor 144, the rear pod 38 has an associated rear pod ram 146 and a rear pod position sensor 148, and the left pod 42 has an associated left pod ram 150 and a left pod position sensor 152.
- 5
- 10 The pod rams 138, 142, 146, 150 control orientation of the pods relative to the legs such that the front and rear pods 30, 38 may be angled upwardly or downwardly as appropriate, and the side pods 34, 42 may be angled to one side as appropriate. For example, if the water craft becomes airborne, the front and rear pods 30, 38 may be angled upwardly so as to prevent the skis from digging into the water on landing. Also,
- 15 when the water craft is turning, the side pods 34, 42 may be angled to one side so as to restrict side slippage of the water craft.

- It will be understood that the above embodiments are for illustrative purposes only, and that in practice the chassis 12, 74, 78 would be enclosed by a body formed of any appropriate material such as plastics, direct or cast GRP, foam sandwich, roto moulded plastics or aluminium, and so on. The legs and pods could also be constructed of any appropriate material such as plastics, plastics incorporating carbon fibre or fibreglass with or without foam infills, foam sandwich, and so on. Larger craft may be provided with legs, a body and pods which incorporate truss members of alloy material such as 6061T6 so as to provide strength and rigidity. Such truss members may be covered with plastics material or alloy skin so as to define inner spaces which may be used to accommodate cargo, stowage, fuel, engines, passenger spaces, and so on.
- 20
- 25

- It will also be understood that any suitable type of propulsion means is envisaged. For example, the water craft may be provided with an engine and/or jets, with sails, with propulsion means arranged to harness power from waves, and so on.
- 30

It will also be understood that the amount of fluid in the conduits may be varied so as to actively adjust the inclination of the chassis 78, to modify the response to roll-type and/or pitch-type forces, to raise or lower the chassis 78 according to the conditions, and so on.

5

For example, prior to initial movement of the water craft 77, sensors may be used to determine the inclination of the chassis 78 and appropriate modifications made to the amount of fluid in the hydraulic circuits so as to raise or lower or so as to make the chassis 78 relatively level. Also, for water craft 77 intended to travel at high speed as  
10 planing-type water craft, the pods 30, 34, 38, 42 may be lifted clear of the water so as to reduce drag at low speed. With such a planing-type water craft, the chassis 78 would be enclosed in a hull which operates as a displacement-type water craft at low speed and which lifts clear of the water at relatively high speed. With this type of water craft, the unsprung weight of the legs and pods should be as low as possible so that the legs and  
15 pods are able to move rapidly up and down during use. With displacement-type water craft such as yachts, the legs and pods should be relatively heavy but should be buoyant enough to hold the body of the water craft clear of the water during use. To achieve increased weight in the pods, auxiliary engines, generators and so on may be located in the side pods so as to provide extra weight to sides of the water craft to help prevent  
20 heeling over during use.

Adjustments to the fluid in the hydraulic circuits may be carried out using a control circuit 154 as shown in Figure 11.

25 The control circuit 154 includes a primary electronic control unit (ECU) 156 arranged to control the amount of fluid in the hydraulic circuits and thereby control the height and orientation of the chassis 77 and the orientation of the pods 30, 34, 38, 42.

The control circuit 154 also includes control conduits 158 for transferring fluid to and  
30 from the hydraulic circuits interconnecting the leg rams, each control conduit 158 being connected in fluid communication to one of the link conduits 126, 128, 130, 132.

The control conduits 158 are also connected to a pressure manifold 160 and a return manifold 162. The pressure manifold 160 is arranged to selectively direct fluid to one or more of the control conduits 158 under control of the primary ECU 156 via first control lines 164. The return manifold 162 is arranged to selectively drain fluid from one or more of the control conduits 158 under control of the primary ECU 156 by the first control lines 164.

The pressure manifold 160 and the return manifold 162 are in circuit with a fluid tank 166 and a hydraulic pump 168. During use, fluid to be pumped into one or more of the control conduits 158 travels from the fluid tank 166 and through the pump 168 and a pressure conduit 170 to the pressure manifold 160. Similarly, during use fluid to be drained from one or more of the control conduits 158 travels from the return manifold 162 through a return conduit 172 to the tank 166.

In order to facilitate selectability of appropriate control conduits 158, the pressure manifold 160 and the return manifold 162 may be provided with valves controllable by the primary ECU 156. The valves may be of any suitable type, such as solenoid, poppet or spool valves.

The control circuit 154 also includes pod conduits 174 for transferring fluid to and from the pod rams 138, 142, 146, 150 so as to adjust the orientation of the pods relative to the legs as necessary. The pod conduits 174 are in fluid communication with a delivery manifold 176 and a return manifold 178, the delivery manifold 176 and the return manifold 178 being controllable by the primary ECU 156 so as to selectively direct fluid to and selectively drain fluid from chambers of the pod rams 138, 142, 146, 150.

The delivery manifold 176 and the return manifold 178 are disposed in circuit with the fluid tank 166 and the hydraulic pump 168. During use, fluid to be introduced into selected chambers of the pod rams travels from the fluid tank 166, and through the pump 168 and the delivery manifold 166 to the appropriate one or more of the pod conduits 174. Similarly, during use fluid to be drained from one or more of the chambers of the pod rams travels through an appropriate one or more of the pod

conduits 174, through the return manifold 178 and into the tank 166.

In order to facilitate selectability of appropriate pod conduits 174, the delivery manifold 176 and the return manifold 178 may be provided with valves controllable by the  
5 primary ECU 156.

In order to determine the appropriate adjustment conduits 158 and pod conduits 174 in which to introduce fluid and from which to drain fluid, various sensors may be provided to determine the orientation of the water craft 77 and the forces exerted on the water  
10 craft. In this example, sensors include a lateral force sensor 182, a pitch force sensor 184, a yaw force sensor 186 and a steering position sensor 188. The primary ECU 156 also uses the pod position sensors 140, 144, 148, 152 to establish the current position of the pods.

15 The control circuit 154 also includes regenerative dampers 190 arranged to provide an adjustable level of damping under control of the primary ECU 156.

In this example, two regenerative dampers 190 are provided, each of the regenerative dampers 190 including a gear motor 192 connected in circuit with one of the upper  
20 conduits 110, 114, 118, 122 connecting upper chambers of an adjacent two leg rams. The gear motor is caused to turn when fluid is transferred between upper chambers of the adjacent rams. Mechanically connected to the gear motor 192 is an electrical generator 194 which generates electricity when a rotor of the generator 194 is turned. The output signal produced by the generator 194 is then rectified and regulated so as to  
25 provide a constant DC output voltage which is used to provide a recharge current for a battery 196. By controlling the magnitude of the recharge current, the level of damping can be controlled since the force required to rotate the rotor of the generator will increase as the recharge current increases. The magnitude of the recharge current may be controlled by a secondary ECU 198 or by the primary ECU 156. If the battery is  
30 fully charged, a resistor bank could be switched in to lose the excess power as heat. The battery could be used to power at least the electronics associated with the regenerative dampers 190, potentially the electronics associated with the control circuit 154, and/or

bilge pumps, craft levelling pumps, small propulsion motors, and so on.

As an alternative regenerative damper, a mechanical damper strut could be incorporated into the hydraulic circuits, the damper strut including a permanent magnet piston portion and a cylinder portion provided with conductive coils. The arrangement is such that as the piston moves relative to the coils, an electric current is generated which may be rectified, converted to DC and used to recharge a battery as with the above described regenerative damper 190. The number of coils, the density of the coils and the magnitude of the charge current would define the damping level.

10

Referring to Figure 12, there is shown a further alternative water craft 200 in accordance with a further alternative embodiment of the present invention. Like features are indicated with like reference numerals.

15 The water craft 200 operates in a similar way to the water craft shown in Figures 7 to 10 in that legs of the water craft are interconnected using hydraulic circuits so that roll and pitch motions of the water craft 200 are restricted without restricting individual motions of the legs.

20 However, unlike the embodiments shown in Figures 7 to 10, the water craft 200 includes six legs disposed in a rectangular configuration with two front legs 202, 204, two central legs 206, 208 and two rear legs 210, 212. Each of the legs is pivotably connected to a chassis portion (not shown) in any suitable way, for example using hinge connections as with the embodiment shown in Figures 7 to 10.

25

An end of a front left leg 202 is provided with a front left pod 214. An end of a front right leg 204 is provided with a front right pod 216. An end of a central left leg 206 is provided with a central left pod 218. An end of a central right leg 208 is provided with a central right pod 220. An end of a rear left leg 210 is provided with a rear left pod 222. An end of a rear right leg 212 is provided with a rear right pod 224.

30

As with the embodiment shown in Figures 7 to 10, two rams 226, 228, 230, 232, in this

example hydraulic rams, are flexibly connected between each leg and the chassis portion. Each adjacent pair of left legs 202, 206, 210 and each adjacent pair of right legs 204, 208, 212 are connected together such that upper chambers of adjacent rams are connected together in fluid communication and lower chambers of adjacent rams are connected together in fluid communication. Upper chambers of frontmost rams 234 associated with the front legs 202, 204, and which are not connected in fluid communication to a ram of an adjacent leg on the same side, are connected together in fluid communication. Similarly, upper chambers of rearmost rams 236 associated with the rear legs 210, 212, and which are not connected in fluid communication to a ram of an adjacent leg on the same side, are connected together in fluid communication. As a consequence of these interconnections, movement of one of the legs in a generally vertical direction tends to cause movement of an adjacent leg in an opposite vertical direction and, in this way, the chassis (not shown) of the water craft 200 is encouraged to maintain a substantially stable inclination as the water craft progresses through an uneven water surface.

The front left leg 202 and the central left leg 206 are also functionally linked to the central right leg 208 and the rear right leg 212 by connecting upper chambers of adjacent front left rams 226 associated with the front left leg 202 and the central left leg 206 in fluid communication with lower chambers of adjacent rear right rams 232 associated with the central right leg 208 and the rear right leg 212, and by connecting lower chambers of the rear right rams 232 in fluid communication with upper chambers of the front left rams 226. This ensures that the front left leg 202 and the central left leg 206 are restricted from simultaneously moving in an opposite direction relative to the central right leg 208 and the rear right leg 212. Similarly, upper chambers of adjacent front right rams 228 associated with the front right leg 204 and the central right leg 208 are connected in fluid communication with lower chambers of adjacent rear left rams 230 associated with the central left leg 206 and the rear left leg 210, and lower chambers of the front right rams 228 are connected in fluid communication with upper chambers of the rear left rams 230. This ensures that the front right leg 204 and the central right leg 208 are restricted from moving simultaneously in an opposite direction relative to the central left leg 206 and the rear left leg 210.



As with the embodiments shown in Figures 7 to 10, accumulators 134 and damper valves 136 are provided so as to provide a degree of resilience to rapid pod motions and to resolve spike loads.

5

Operation of the water craft 200 will now be described.

10 If during use one of the pods encounters a wave crest, the leg associated with the pod is urged to move upwards relative to the chassis thereby causing compression of the respective rams associated with the leg. This causes fluid to flow in each of the respective hydraulic circuits defined by the front left rams 226, the front right rams 228, the rear left rams 230, the rear right rams 232, the frontmost rams 234, and the rearmost rams 236. As a result, adjacent legs move in opposite directions.

15 If during use an adjacent two pods on the same side, for example the front left pod 214 and the central left pod 218, encounter a wave crest, both the front left leg 202 and the central left leg 206 are urged to move upwards relative to the chassis. Since the front left leg 202 and the central left leg 206 are functionally linked to the central right leg 208 and the rear right leg 212, upwards movement of the front left leg 202, and the  
20 central left leg 206 causes upwards movement of the central right leg 208 and the rear right leg 212. At the same time, fluid flows in each of the circuits defined by the front right rams 228, the rear left rams 230, the frontmost rams 234, and the rearmost rams 236 which causes the front right leg 204 and the rear left leg 210 to move downwards relative to the chassis.

25

If during use the water craft 200 experiences a roll type force which tends to tilt the chassis of the water craft relative to the pods in the roll plane and which tends to submerge all pods on one side, for example the left pods 214, 218, 222, and lift the right pods 216, 220, 224, resistance to upwards movement of the left legs 202, 206, 210 and  
30 resistance to downwards movement of the right legs 204, 208, 212 is provided by virtue of the functional linking between the front left rams 226 and the rear right rams 232 and the functional linking between the front right rams 228 and the rear left rams 230. In

this way, resistance is provided to roll forces and the chassis portion of the craft is encouraged to maintain a stable inclination.

5 If during use the water craft 200 experiences a forward pitch type force which tends to submerge the front pods 214, 216 and tilt the body of the water craft forwards, significant upwards movement of the front legs 202, 204 will be resisted by virtue of the interconnection between upper chambers of the frontmost rams 234. However, since accumulators 134 are provided in circuit with the frontmost rams 234, a degree of resilience is provided to assist in absorbing the impact of the wave crest.

10

Although the present embodiment has been described in relation to leg pairs which are functionally linked to diagonally opposite leg pairs, it will be understood that other variations are possible. For example, each pair of adjacent legs may be functionally linked to a pair of transversally opposite legs.

15

It will also be understood that although the present embodiment is described in relation to a water craft having six pods and associated legs arranged in a rectangular configuration, other variations are possible, such as four pods and associated legs arranged in a square configuration.

20

It will also be understood that other features which are discussed above in relation to the embodiments shown in Figures 7 to 10 and which are applicable to the present embodiment may also be included where appropriate. For example, regenerative dampers 190 may be included to provide an adjustable level of damping control.

25

It will also be understood that instead of providing regenerative dampers in circuit with the conduits connecting chambers of the rams, other arrangements for providing an adjustable level of damping are possible. For example, a regenerative damper system may be provided wherein each of the pods have an associated regenerative damper 240 as shown in Figure 13. Like features are indicated with like reference numerals.

30

The regenerative damper 240 includes a double acting ram 242 disposed between a leg

and the chassis such that movement of the leg relative to the chassis during use effects compression or expansion of the ram 242. Chambers of the ram 242 are connected in fluid communication with a gear motor 192 using conduits 244 so that, during use, compression and expansion of the ram 242 causes fluid to flow through the conduits 244 and thereby the gear motor to rotate. An electrical generator 194 is in mechanical connection with the gear motor 192 and is caused to generate an electrical current when the gear motor 192 rotates. The electrical current produced by the generator 194 is supplied to a rectifier 246 which produces a full-wave rectified electrical current. The rectified current is supplied to a battery 196 as a battery recharge current. The magnitude of the charge current supplied by the rectifier 246 is adjustable using any suitable controllable regulator, the charge current magnitude being proportional to the force required to rotate the rotor of the generator 194 and to the level of damping produced by the regenerative damper 240.

The regenerative damper 240 also includes an electronic control unit (ECU) 248 and a position sensor 250, the position sensor 250 providing the ECU 248 with information indicative of the position of the respective pod. The ECU 248 may be arranged to control the regulator so as to modify the charge current magnitude and thereby the damping level using the information from the position sensor 250.

It will be understood that although a position sensor is shown in Figure 13, other sensors may also be provided for sensing behaviour of the water craft or parts of the water craft during use, such as steering sensors, G-force sensors, and so on.

It will also be understood that by providing each pod with an associated regenerative damper 240 as shown in Figure 13 and controlling the regenerative dampers using appropriate sensors and an ECU, a regenerative damping system can be constructed for a water craft wherein the level of damping for each pod is individually controlled so as to selectively control pitch and roll motions of the water craft during use.

An alternative regenerative damper system 260 is shown in Figure 14. Like features are indicated with like reference numerals. Operation of the alternative regenerative

damper system 260 is essentially the same as operation of the regenerative damper system described in relation to Figure 13 in that appropriate sensors and an ECU are used to achieve individual control of damping for each pod by modifying the magnitude of a rectified current generated as a result of expansion and contraction of a ram during use.

The alternative regenerative damper system 260 includes several alternative regenerative dampers 262. Each alternative damper 262 includes a double acting ram 264 having a permanent magnet piston head 266. Wound around the ram 264 is an electrically conductive coil 268, in this example of copper material. Chambers of each ram 264 may be connected to each other through a bypass conduit 270 or may be open-ended so that chambers of the ram communicate with atmosphere. Ends of the coil 268 are connected to a rectifier 246.

As with the regenerative damper system described above in relation to Figure 13, each of the regenerative dampers 262 is disposed between a leg and the chassis so that, during use, movement of the respective leg relative to the chassis effects contraction or expansion of the regenerative damper 262. However, with the regenerative damper system 20 shown in Figure 14, instead of expansion and contraction of the ram 264 driving a gear motor and a generator, in this example expansion and contraction of the ram 264 causes movement of the permanent magnet relative to the surrounding coil and thereby generation of an electrical current through the coil 268.

As with the regenerative damper system described above in relation to Figure 13, any appropriate sensors may be provided, such as a position sensor 250 and a steering sensor 251, in order to sense the behaviour of the water craft or parts of the water craft during use.

As with the regenerative damping system described above in relation to Figure 13, the level of damping provided by each regenerative damper 262 is selectable by modifying the magnitude of the charge current supplied to the battery 196, in this example the magnitude of the charge current being proportional to the magnitude of current drawn

from the coils 268 and the magnitude of resistance to movement of the piston head relative to the coil.

Modifications and variations as would be apparent to a skilled addressee are deemed to  
5 be within the scope of the present invention.

DATED this 26<sup>th</sup> day of February 2003

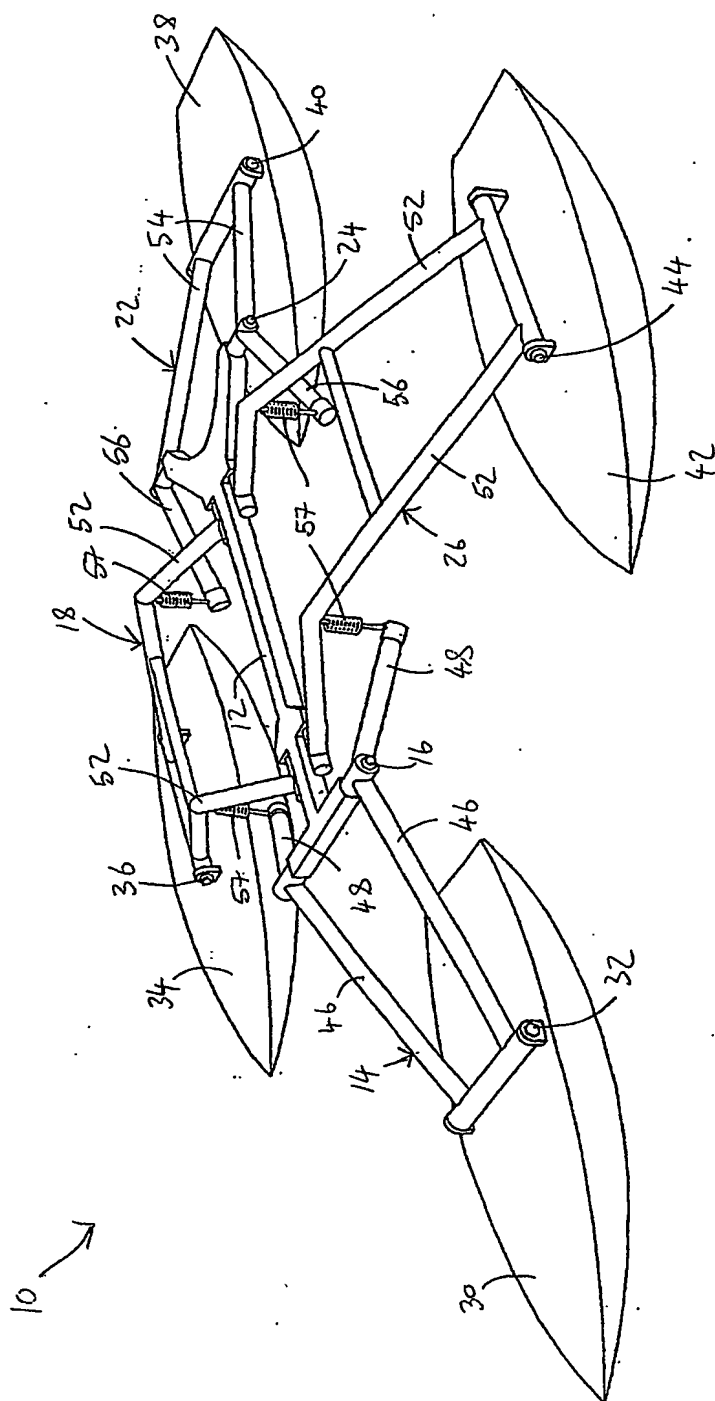
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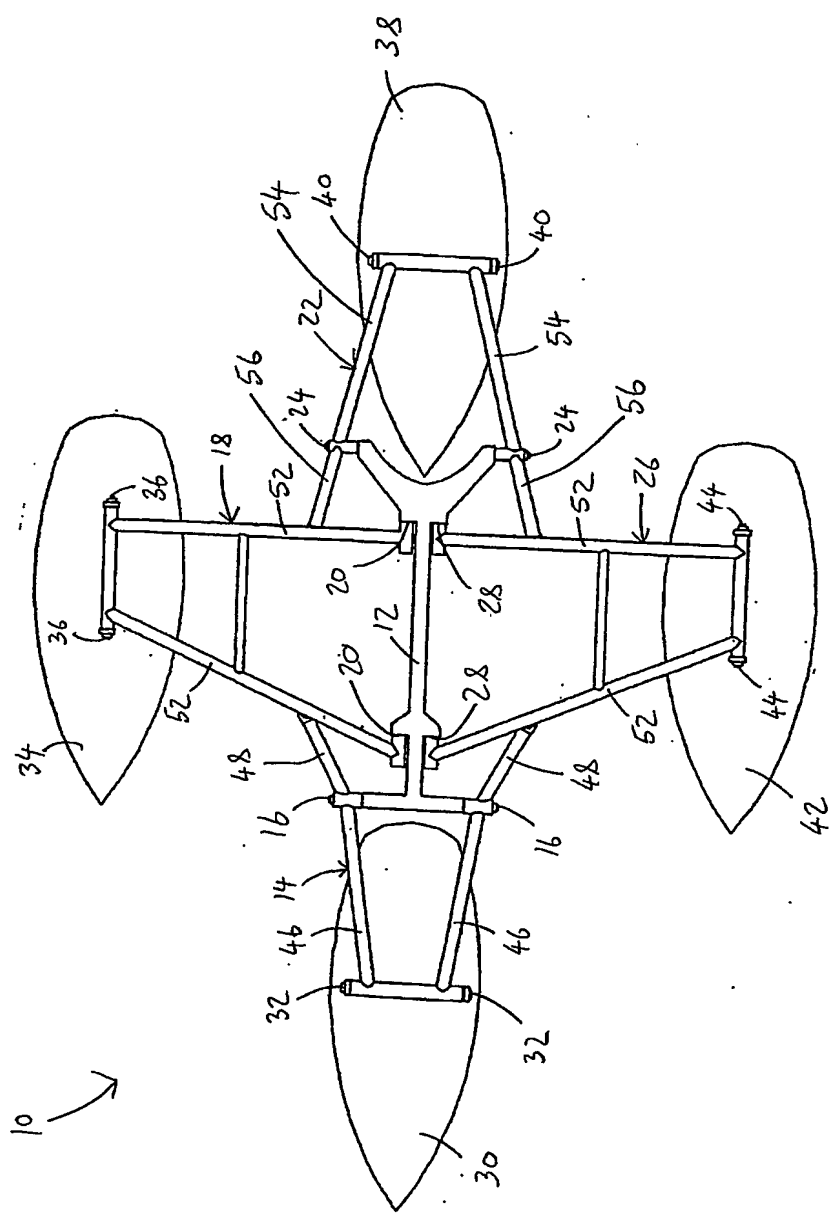


Fig 2.

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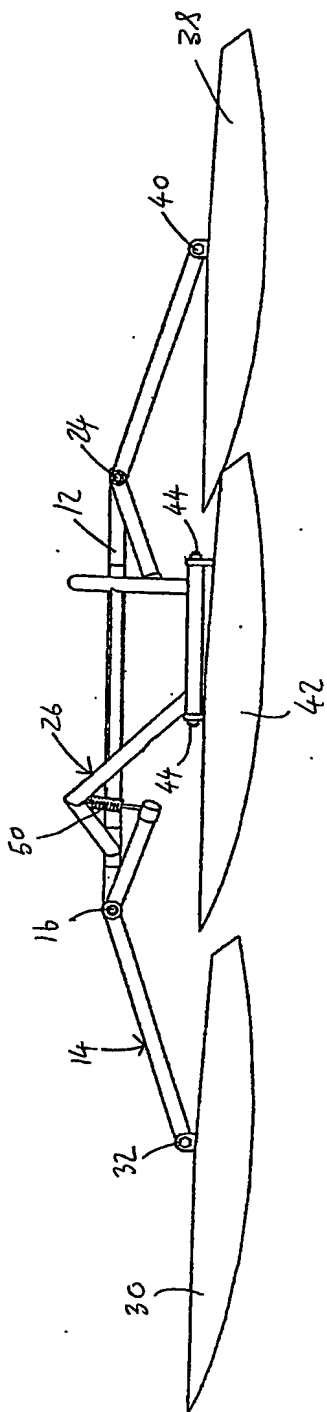


Fig 3



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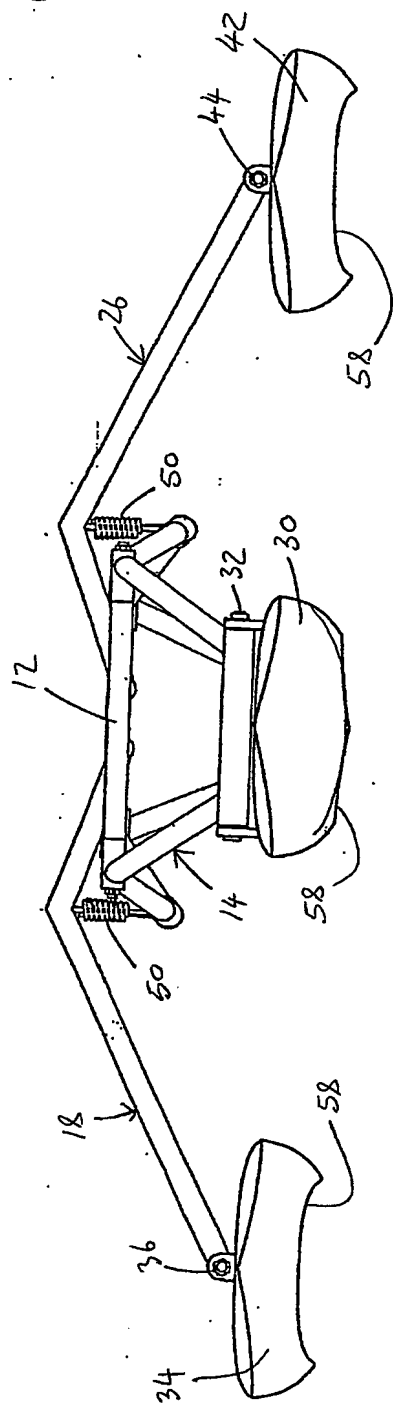
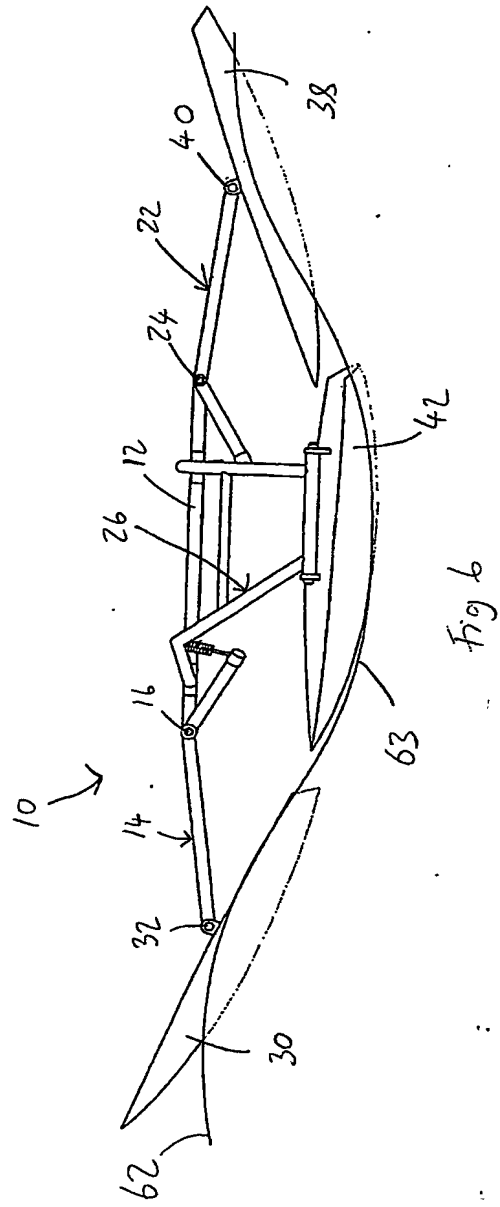
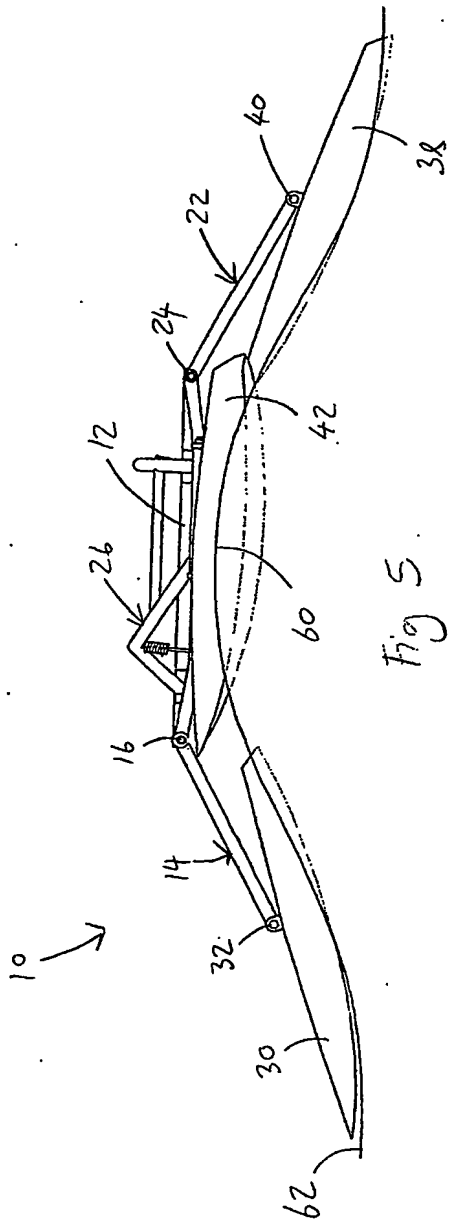


Fig 4



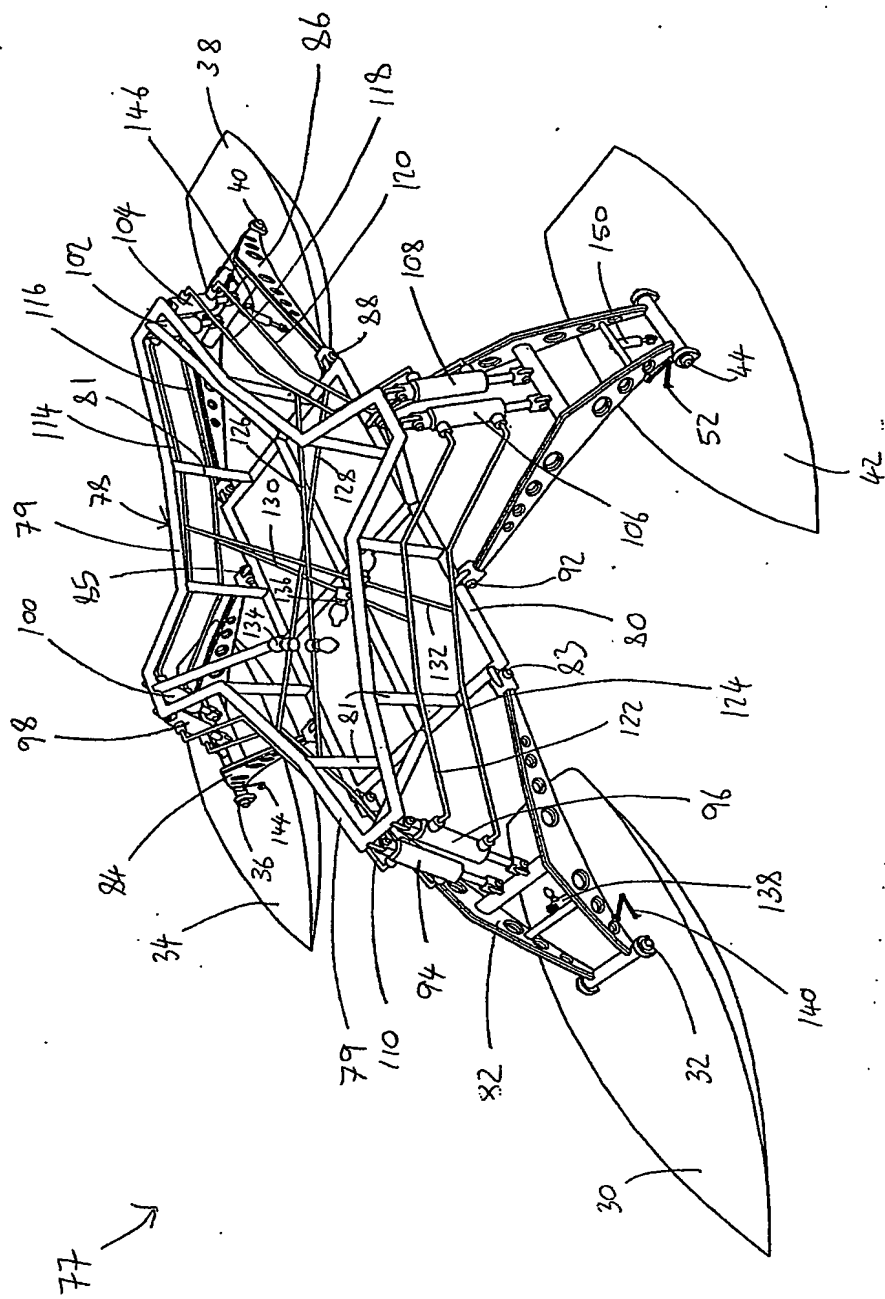
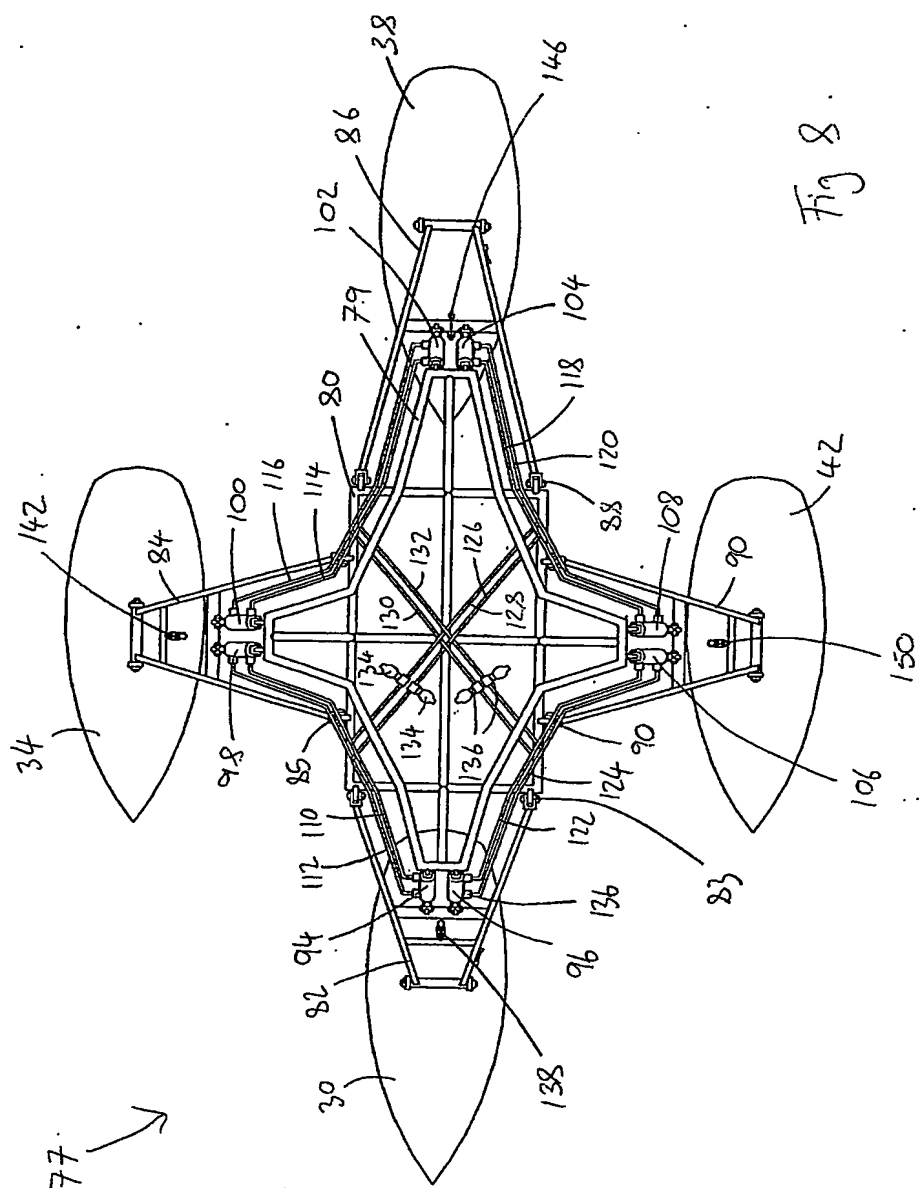


Fig 7.



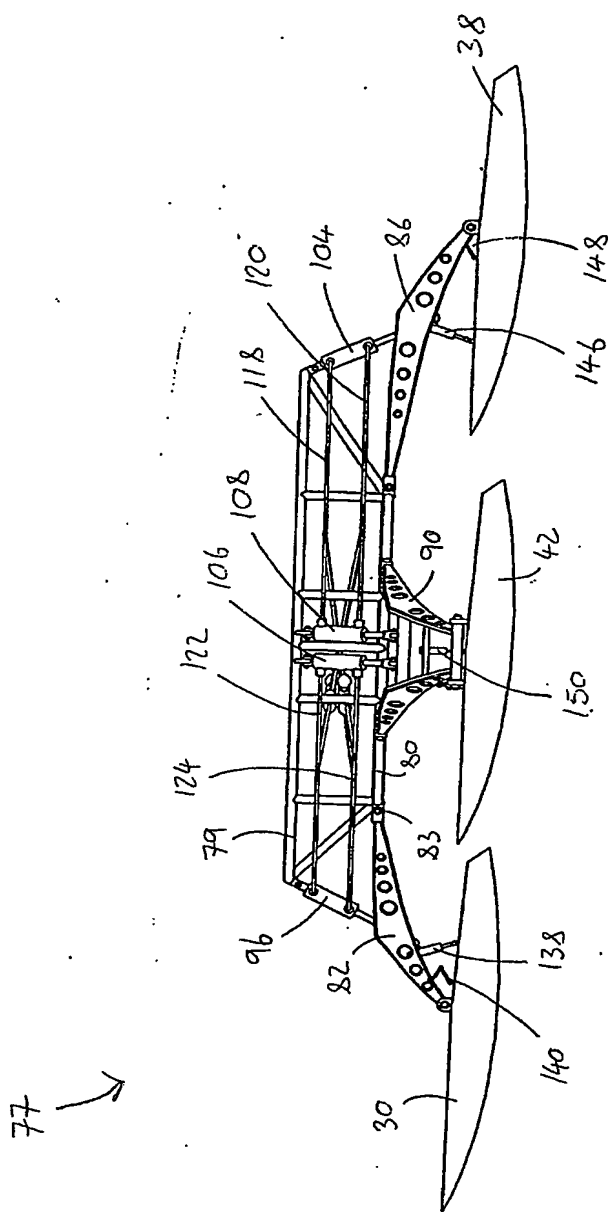


Fig 9.

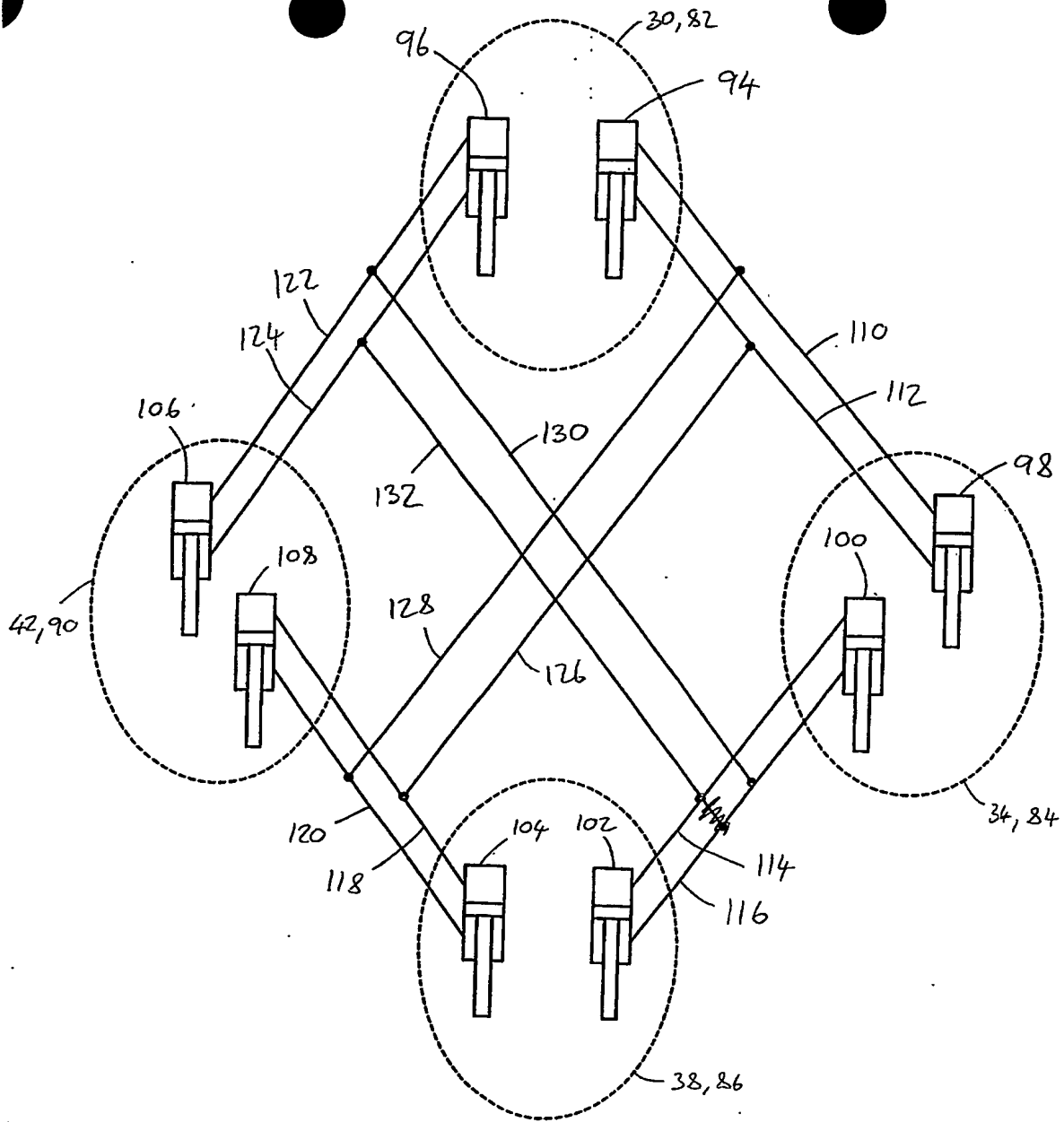


Fig 10

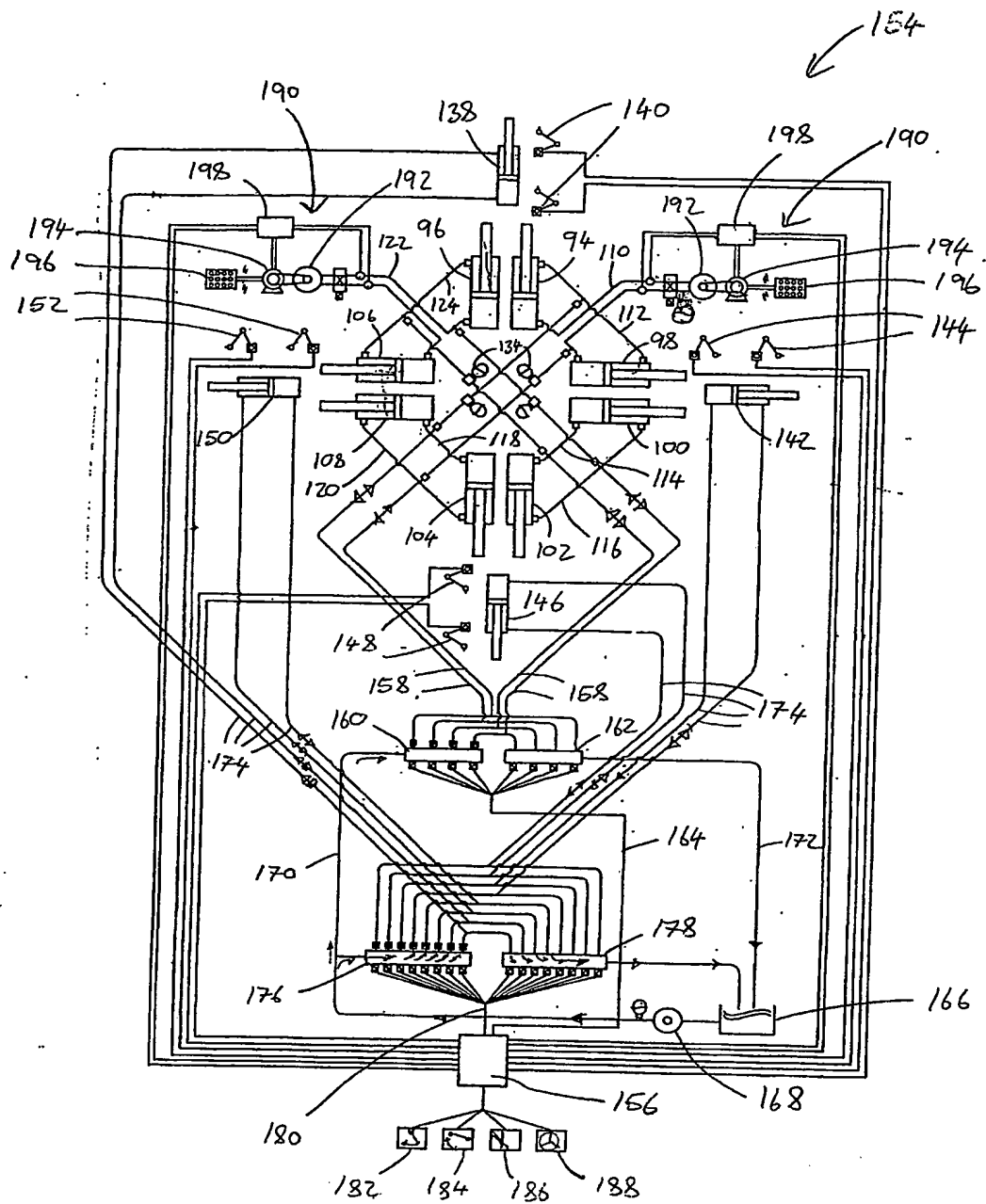


Fig 11

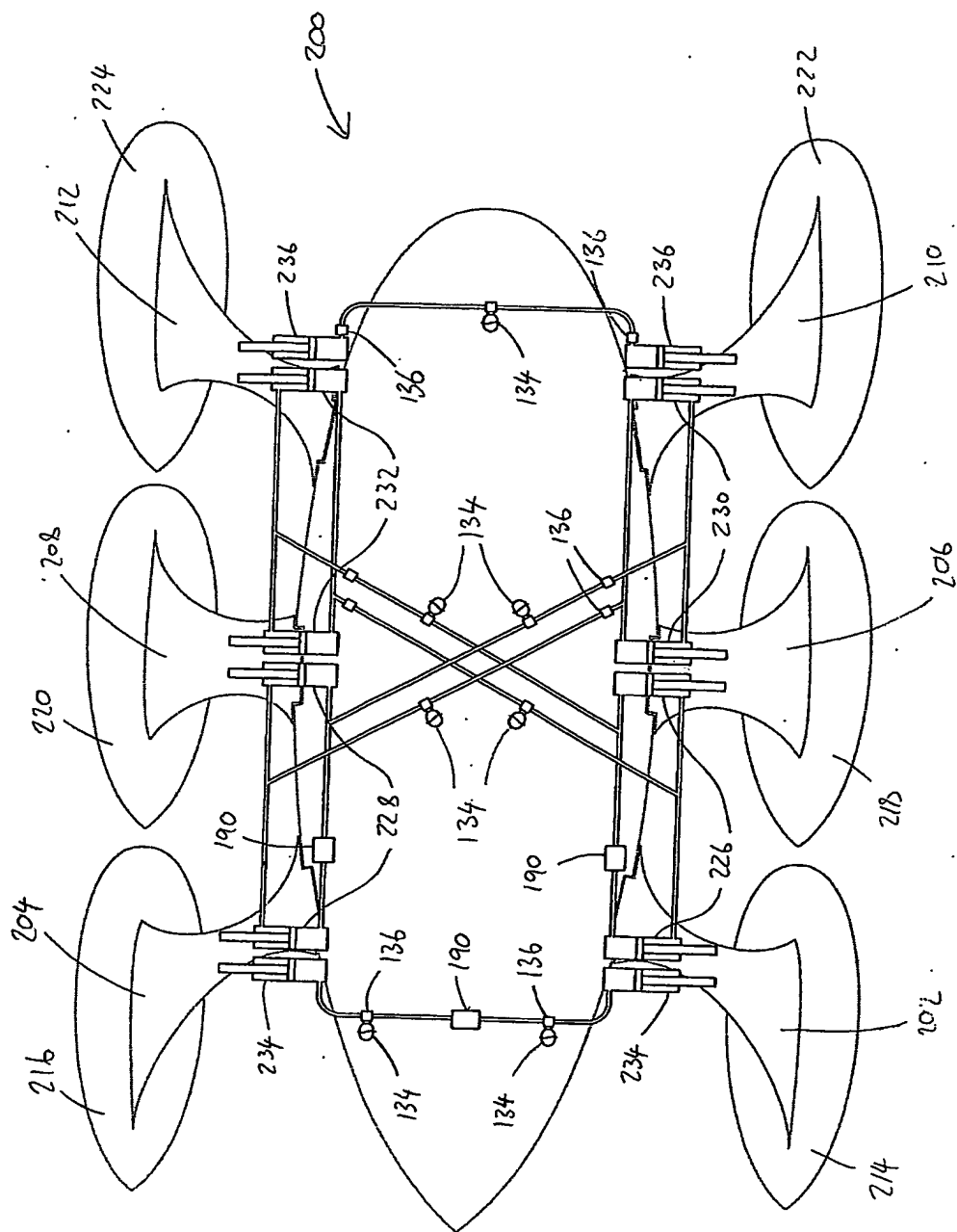


Fig 12.



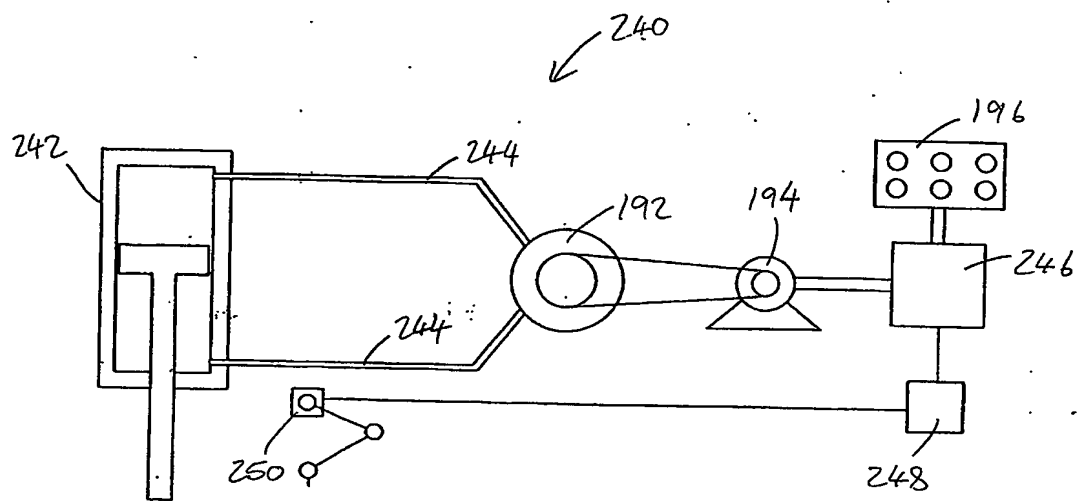
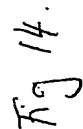


Fig 13.



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